

The Value of Upsloping ST Depression in Diagnosing Myocardial Ischemia

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We evaluated the value of upsloping ST-segment depression in predicting the severity of myocardial ischemia. Comparison of the exercise electrocardiographic changes was made to myocardial perfusion images and coronary angiograms as the criteria for ischemia. We retrospectively reviewed 621 patients who underwent exercise technetium-99m tetrofosmin single photon emission computed tomography (SPECT) for the assessment of suspected or known coronary artery disease followed by coronary angiography within a 3-month period. The test sensitivity and specificity of 1 mm horizontal or downsloping ST depression in predicting reversible ischemia as assessed by gated SPECT imaging (GSI) were 65% and 87%, respectively. The corresponding values were 67% and 94% compared to coronary angiography. The sensitivity and specificity of gated SPECT imaging compared to coronary angiography were 78% and 89%. On the other hand when 1 mm upsloping ST depression at 70 ms past the J-point was regarded as abnormal, along with horizontal and downsloping, the sensitivity and specificity were 82% and 90% compared to myocardial perfusion imaging, and 77% and 92% as assessed by coronary angiography. We conclude that upsloping ST-segment depression is associated with an increased risk of coronary artery disease and is a valuable predictor of myocardial ischemia.

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The significance of upsloping ST segments observed during exercise testing has been a controversial subject in exercise literature. For years, many recognized experts in the field, including Froelicher,¹ have advocated that upsloping ST-segment depression does not indicate ischemia. Most recently, the same authors have conceded that this pattern is indeed associated with an increased risk of coronary artery disease. Numerous conflicting reports have also been published relying heavily on myocardial perfusion imaging rather than the coronary angiogram as an indicator of ischemia and thus correlating upsloping ST segment that way. Sansoy² suggests that the upsloping pattern ought to be used when interpreting an exercise test as it significantly improves sensitivity. At the same time, Desai³ suggests that it would be reasonable to consider patients with slow upsloping ST depression during exercise as having a very low likelihood of CAD. From our previously published material,⁴ the upsloping ST segment is considered to indicate ischemia if, at 80 ms after the J-point, the segment is 1.5 mm below the baseline level of the PQ junction.

In our present investigation, we aimed at evaluating the value of upsloping ST-segment depres-

sion in predicting the severity of myocardial ischemia by comparing the exercise electrocardiographic changes to both myocardial perfusion imaging and coronary angiography. The goal was to provide an accurate, comprehensive review of the upsloping ST-segment pattern by employing a large cohort of patients and assessing the severity of myocardial ischemia by the two best means of doing so: myocardial perfusion imaging and coronary angiography.

METHODS

A retrospective analysis of 621 exercise tests on patients who have had nuclear scintigraphy and coronary angiograms within a 3-month period were carried out. The exercise was monitored by a 15-lead electrocardiogram on the Ellestad protocol and patients were urged to continue until a maximum effort was achieved. The exercise protocol starts with an initial 10% grade and a speed of 1.7 miles/h for 3 minutes. The speed then increases to 3-5 miles/h for 2 minutes each over the next 6 minutes without a grade increase. Then, after the first 9 minutes the grade increases to 15%, while the speed remains the same. Recordings were

Table 1. ECG Configuration versus Vessel Disease Study Group (471 patients)

	Single	Double	Triple	Total
Downsloping	53 (41.2%)	24 (18.9%)	52 (39.9%)	129
Horizontal	31 (19.1%)	66 (41.4%)	63 (39.5%)	160
Upsloping	19 (10.6%)	112 (61.5%)	51 (28%)	182

continuously taken from rest through peak exercise to full recovery. All the tracings were taken at 25 mm/s paper speed. Termination of exercise was due to exhaustion, dyspnea, chest pain, leg fatigue, serious arrhythmias or decreasing blood pressure below that recorded at rest. The test was not terminated because the patient had achieved a predetermined predicted heart rate. Exclusions included those who could not exercise for any reason, those with left bundle branch block, unstable angina, recent (within 1 month) myocardial infarction and congestive heart failure. After exercise, patients were asked to recline on a bed for at least 5 minutes. Nuclear scintigrams were done by the injection of Tc99m tetrofosmin IV at near peak exercise. At least 1 minute prior to termination of exercise, 25 mCi (925 MBq) was injected. GSI was acquired 30 minutes–2 hours following the injection of the radioisotope. Rest imaging was acquired 1–3 days later, following the intravenous administration of 25 mCi (925 MBq) Tc99m tetrofosmin.

Coronary angiograms were done by the Judkins approach. The angiograms were reviewed by a cardiologist who was not familiar with the ST-segment changes not part of this study. The lesion diameter was measured by calipers in at least two views. A 70% or greater diameter narrowing was considered significant for coronary artery disease. This study was composed of 471 patients who had one or more coronary arteries with a lesion judged to be at least 70% stenotic (study group), and 150 patients with coronary artery disease judged to be insignificant or less than 70% stenotic (control group).

Those with ST-segment depression of at least 1 mm, measured at the J-point, were categorized as

upsloping, horizontal and downsloping. When several different patterns were present at different times and in different leads the designation was based on the lead with the most severe change, i.e., upsloping equals less severe, horizontal equals intermediate severity and downsloping equals most severe.

Statistics

Qualitative (categorical) data are presented as number (percent) and quantitative (continuous) data as mean (standard deviation). The chi-square test was used to test the significance of relationship (correlation) between the configuration of depressed ST segments during and after treadmill exercise, and severity of disease (¹Vessel, ²Vessel, and ³Vessel) as dependent variable (outcome). As the level of all variables (DV and IV) are ordinal, the Mantel-Haenzel chi-square test was also used. Logistics regression was applied to find odds ratio for the independent variables. The analysis was repeated for the size of reversible perfusion defects as another outcome. Data were analyzed with SPSS (Version 10) and SAS (Version 6.12/8.0). A 2-tailed P value of <0.05 was considered significant for all parts.

RESULTS

Of those with downsloping ST depression, 62% had a large reversible ischemic area, 34.5% a moderate and 0.7% a small area, while 3% had no reversible ischemia. When they had horizontal ST depression, 25.5% had a large area of reversible

Table 2. ECG Configuration versus Size of Reversible Ischemia

Configuration		Nuclear Results				Total
		None	Small	Moderate	Large	
Downsloping	Count	4 (3)	1 (0.7)	44 (34.3)	80 (62)	129
Horizontal	Count	20 (12.5)	13 (8)	86 (54)	41 (25.5)	160
Upsloping	Count	44 (24)	40 (22)	61 (33.5)	37 (20.5)	182

Table 3.

	Sensitivity		Specificity	
	Gated SPECT	Angiogram	Gated SPECT	Angiogram
Horizontal/downsloping	65%	67%	87%	94%
All ST depression	82%	77%	90%	92%
Gated SPECT versus angiogram		78%		89%

ischemia, 54% a moderate area, 8% a small area and 12.5% none. When they had upsloping ST depression 20.5% had a large area of reversible ischemia, while 33.5% had moderate, 22% small area and 24% no reversible ischemia. Thus, a downsloping ST depression suggests the most extensive ischemia, while horizontal remains as the marker for a moderate process and an upsloping pattern indicates significant but smaller size. Of those with downsloping ST depression 39.9% had triple vessel disease, 18.9% double and 41.2% single vessel disease. When they had horizontal ST depression 39.5% had triple vessel disease, 41.4% double and 19.1% triple vessel disease. Of those with upsloping ST depression 28% had triple vessel disease, 61.5% double and 10.6% single vessel disease.

DISCUSSION

The major weakness of routine treadmill testing, when used to diagnose coronary artery disease, is low sensitivity. Although evidence that upsloping ST depression contributes to the identification of coronary disease has been available for many years, for some reason it has largely been ignored. Published studies, comparing the exercise EKG to exercise nuclear imaging and exercise electrocardiography usually are limited to horizontal and downsloping ST segments with the stipulation that upsloping ST patterns are considered to be normal. Thus, it is generally believed that exercise tests with imaging have a higher sensitivity than those with EKG changes. Although our data indicated that upsloping configuration identifies a lesser degree of ischemia on an average, 20% of our patients with this configuration had a large area of reversible ischemia on the gated SPECT acquisition and 28% had triple-vessel disease on coronary angiography. Consequently, when upsloping ST changes are included as abnormal, the sensitivity of the exercise EKG increases to 82% when compared to the gated SPECT imaging and 77% when using the angiogram as the gold standard. It would appear that when

upsloping ST segment changes are included with the others, namely horizontal and downsloping, the sensitivity is increased by 15% and the specificity is about the same. In conclusion, using the EKG changes alone may be equivalent to exercise testing with imaging and it is certainly more cost-effective.

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